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Subtle, Natural and Socially Acceptable Interaction Techniques for Ringterfaces ─ Finger-Ring Shaped User Interfaces

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Abstract. This study analyzes interaction techniques in previously proposed 16 user interface concepts that utilize the form factor of a finger-ring, i.e. "ringterfaces". We categorized the ringterfaces according to their interaction capabilities and critically examined how socially acceptable, subtle and natural they are. Through this analysis we show which kind of ringterfaces are likely to become general-purpose user interfaces and what factors drive their development toward commercial applications. We highlight the need for studying context awareness in ambient intelligence environments and end-user programming in future research on ringterfaces.

Keywords: Interaction techniques, Subtle interaction, Social acceptability, Natural user interface, Finger-ring.

1 Introduction

Social acceptability and unobtrusiveness are becoming an ever higher concern in the development of ambient intelligence technology and innovative user interfaces [1, 2]. The aim in ambient intelligence technology is to make the technology 'disappear' and become socialized and part of the everyday activities of people. Jewelry has been noted as the potential medium for this purpose. Over a decade ago Miner et al. [3] envisioned digital jewelry as ambient interfaces that enable the user to see incoming email messages, check priority emails in meetings and provide affective information by using dynamically color-coded jewelry to close friends. Some of this kind of use is now enabled by smartwatches. Also finger-rings seem suitable as a universal form of ambient technology. Wide social acceptability in almost all cultures and the fact that fingers produce the highest information entropy in the human body [4] make finger-rings a good candidate for future interaction device.

Finger-ring shaped user interfaces deserve a descriptive term of their own in HCI literature ─ "ringterfaces". In this paper we present a literature review of 16 past ringterface concepts and an analysis of interaction techniques. We discuss the pros and cons of these ringterfaces for their input and output capabilities and critically examine how socially acceptable, subtle and natural they are. We end by suggesting factors that can drive ringterfaces to become everyday digital jewelry.

This analysis focuses only on academic literature. We recognize that there are commercial products such as the gaming appliance *Ringbow*. There are also related patents pending and granted. Since none of the ringterfaces have really reached large scale commercial utilization we exclude those concepts from this analysis for now.

2 18 Years of Research ─ 16 Ringterface Concepts

This chapter summarizes the evolution of ringterface concepts from the first wireless keyboard prototypes in the 90's to the latest gesture ringterfaces in 2012. We then categorize the ringterfaces by the interaction techniques they support.

2.1 Ringterface Concepts and Prototypes

FingeRing in 1994 [5] and 1997 [6] was the first widely noted prototype that utilized the form factor of a finger-ring as the user interface. FingeRing was intended as a “full-time wearable interface” for inputting commands and characters by tapping a surface with fingertips which was detected by accelerometers and mapped to characters on the keyboard.

MIDS Ring [7, 8] developed by Lam et al. works as a mouse, virtual keyboard and a light pen. The system uses MEMS acceleration sensors and consisted of MIDS Ring, MIDS Watch, MIDS Interface and a computer. It was envisioned to become the interface for handwriting or playing virtual piano and assistive technology for the blind for reading Braille dot writings.

Fukumoto's HANDset [9] acts as a phone. It uses vibration conductivity of the bones in the user's hand for transmitting phone calls. The ring part of the system is used as the speaker and the wrist part as microphone. The user inserts her finger in the ear canal and speaks to her wrist. Additionally, the system supports a simple gesture such as on/off which is achieved by tapping fingertips together. Although intended primarily as a phone the device itself can be count as a ringterface since an audio-based input and output mechanism could be built on it.

Telebeads by Labrune & Mackay [10] was a concept for sharing social network mnemonics targeting teenagers. The finger-ring part of the system acted as a notification medium to e.g. vibrate when someone sent a message to the user. Telebeads also help people to remember who they are connected to and communicate with them using the ring. For simple input Telebeads included a button.

Lee et al.'s i-Throw [11] was the first ringterface to realize a wide range of hand gestures for user interaction. i-Throw was the ringterface part of a larger smart ubiquitous environment. The system recognizes gestures such as throwing (sending), ready-to-receiving, receiving and selecting virtual objects, as well as scrolling up or down, increasing or decreasing (e.g. volume), and scanning. Target devices the user wishes to interact with are chosen by pointing at them at close range.

Han et al. [12] presented the first ringterface to make use of magnetometers. Their method for handwriting input uses a magnetometer attached to the wrist and a permanent magnet worn as a finger-ring. They suggested the method could be applied for wearable computing.

Iwamoto & Shinoda [13] demonstrated a ring shaped interfaces that allows the user to press UbiButtons by tapping different parts of the index finger and use the finger as a pointing device such as mouse.

Werner et al.'s [14] United-Pulse ringterface measures and transmits the partner's pulse whenever the wearer touches the ring having the aim of for sharing intimacy.

Abracadabra by Harrison et al. [15] uses magnetometers like Han et al., but it requires a wrist display. The system supports 1D polar movement (rotation) and clicking, cursor control and 1D polar or 2D positional gestures that are done near but not directly on the display ("around device interaction").

Matsuda et al. [16] developed a Finger Braille reading system for deafblind people which consists of piezoelectric accelerometers attached to rings. Finger Braille writings are recognized when moving fingers over Braille dots.

Nenya developed by Ashbrook et al. [17] uses similar methodology as Abracadabra allowing 1D input operations. The user can twist the ring to make scrollable selections and slide it along the finger to "click". Also Nenya requires a wrist counterpart that recognizes changes in electromagnetic fields that use of the ring produces. It can be used by just one hand although two-handed use is much easier.

Bainbridge & Paradiso [18] created a ringterface based on RFID technology. Passive RFID tags are worn in each finger and a wrist piece contains an RFID reader. Five rings worn on each finger allow finger gestures such as clicking and scrolling and mouse-like operation of the cursor.

Zhang et al. [19] demonstrated a ring-shaped system and a sensing method that collects audio signals conducted by finger bones when the user slides the finger along a surface. It uses a gyroscope and an accelerometer to recognizes posture and movement of the hand. This system was intended to be used for controlling large displays such as TVs and projector systems.

Xangle by Horie et al. [20] consists of two accelerometers embedded on two different devices assuming that people can control only one axis precisely and fast by moving a body part. Xangle devices can be worn on forefingers, a forefinger and a thumb, or a forefinger and head. Pointing interaction is enabled by calculating the angle between the two devices. "Clicking" is achieved by 1-second pointing.

EyeRing by Nanayakkara et al. [21] is a ring-embedded camera that is used for taking photos of the surroundings. It was intended as an assistive technology for the blind to be used in applications such as detection of currency in bills by text recognition, recognition of colors and walking aid by recognizing space in front of the user. A small button embedded on the ring has to be pressed to initiate interaction.

Ketabdar et al. [4] developed an "around device interaction" system Pingu. It consists of built-in magnetometer, acceleration, gyro and proximity, and output capabilities via a RBG led light and a vibration transducer. Pingu recognizes small scale subtle finger gestures. Social interaction, physical activity analysis, context recognition and in-car interaction are mentioned as possible applications.

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2.2 User Interaction Support in Ringterfaces

We categorized the ringterface concepts according to input and output capabilities by using the direct vs. indirect input and user task composition [22]:

- *elemental tasks* use typically one degree of freedom such as 1) text entry (e.g. typing a symbolic character), 2) making a selection (e.g. from a set of alternative), 3) indicating position (e.g. pointing on screen) and, 4) quantification (e.g. giving an exact numerical value),
- *phrasing* that utilizes muscular tension such as using a pull-down menu (press and hold mouse button, move cursor to a menu item, release button).

Compound tasks and chunking that use multiple degrees of freedom e.g. by using two hands for scrolling with keyboard and pointing with mouse are often difficult to differentiate from elemental user tasks [22]. In the case of ringterfaces, it is rather simple to differentiate between elemental and phrasing tasks, but more inconvenient to differentiate between elemental and compound tasks because the discrete motion of the finger(s). Phrasing can be taken as an input operation which requires the finger on which the ring is worn to be kept in certain position for a while, as "clicking" using Xangle. Table 1 illustrates our categorization.

Table 1. Input type and user tasks supported by each ringterfaces concept.

Ringterface	Fingers	Direct/ Indirect input	Elemental tasks	Phrasing tasks	Output
FingeRing	5	Indirect: keyboard	Text	N/A	N/A
MIDS Ring	2	Direct: pen Indirect: keyboard; mouse	Text, Pointing	Hand-writing	N/A
HANDset	1	Direct: voice Indirect: button	“Clicks”	N/A	Audio (voice)
Telebeads	1	Indirect: button	“Clicks”	N/A	Visual (color coding); Vibration (alert)
i-Throw	1	Indirect: gestures	N/A	Hand gestures	N/A
Han et al.	1	Direct: pen	N/A	Hand-writing	N/A
UbiButtons	1	Indirect: mouse	“Clicks”, Pointing	N/A	N/A
United-Pulse	1	N/A	N/A	N/A	Vibration (pulse)
Abracadabra	1	Indirect: gestures; mouse; button	“Clicks”, Pointing	Hand gestures	N/A
Matsuda et al.	3	Indirect: Finger-Braille reading	N/A	N/A	Vibration (Braille)
Nenya	1	Indirect: slider	Selection, “Clicks”	N/A	N/A
Bainbridge & Paradiso	5	Indirect: gestures; mouse; button	Pointing, Selection, “Clicks”	Hand gestures	N/A
Zhang et al.	1	Direct: touchscreen	Pointing, Selection, “Clicks”	N/A	N/A
Xangle	2	Indirect: joystick	N/A	Pointing, “Clicks”	N/A
EyeRing	1	Direct: pointing Indirect: button	“Clicks”	N/A	Audio (synthesized voice)
Pingu	1	Indirect: gestures	N/A	Hand gestures	Visual (color coding); Vibration (alert)

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Since the 90's command-line prototypes the number of rings has been reducing, the only exception being Bainbridge & Paradiso's prototype. Most of the ringterfaces (10) have adopted the indirect input paradigm. Han et al.'s and Zhang et al.'s prototypes enable direct input only. MIDS Ring, HANDset and EyeRing enable both direct and indirect input. The ringterfaces demonstrate a wide array of input methods being either button-like (5), mouse-like (4), gesture interface (4), keyboard-like (2), pen-like (2), joystick-like (1), touchscreen-like (1) or simple slider-like (1). Matsuda et al.'s Braille reading method is also indirect input. United-Pulse does not support any input.

The first two prototypes, FingeRing and MIDS Ring enable text input. Most of the ringterfaces utilizing indirect input methods enable “clicks” (7) and pointing (6) of which Zhang et al.'s prototype acts as a direct touchscreen-like input. Xangle can be taken as an indirect joystick-like method as the user has to adjust two rings to point and make selections. HANDset is a unique ringterface in a sense that it is intended as just a phone and it supports only input that is equal to pressing two buttons. 7 ringterfaces enable phrasing. Handwriting is supported by MIDS Ring and Han et al.'s prototype. i-Throw, Abracadabra, Bainbridge & Paradiso's prototype and Pingu support gesture interaction. Xangle is a unique indirect input ringterface since pointing is done by phrasing and the user has to “click” by holding the cursor still.

6 ringterfaces support output. Output is usually provided via vibro-tactile or audio feedback. Only Telebeads and Pingu demonstrate visual feedback by showing lights of various colors which meaning the user needs to interpret. HANDset was intended as just a phone. Matsuda et al.'s prototype is unique in a sense that its only function is to transfer and interpret vibration information into another person than the user.

3 Analysis of Interaction Techniques

The categorization above demonstrated that it has been technically possible to include many kinds of input methods and at least limited output into ringterfaces. In the following we analyze advantages and disadvantages of the interaction techniques. It should be noted that only limited user studies have been conducted by all the ringterface authors. We recognize the fundamental challenge of defining what subtle interaction, gestures and natural user interaction are in general, but at least we can draw approximations based on previous HCI literature on these topics.

3.1 Analysis Criteria from HCI Literature

Social acceptability. As computer use has become a social norm, we do not question if pressing buttons, making selections, using mouse, typing on keyboard and writing with digital pens are socially acceptable input methods. On the other hand, several ringterfaces support gesture interaction. There are expressive, suspenseful, secretive and magical gestures and the observers of gesture interaction have an impact on what is socially acceptable [23]. In everyday use the effect of gestures has to be visible to the people around the user instead of looking like magic [23]. Therefore ringterfaces that use indirect non-gesture based or direct touchscreen-like interaction techniques can be expected to be socially acceptable as the effects can be observed. Gesture interaction without a touchscreen, however, appears as magical ununderstandable interaction. Secretive gestures would not be noticed at all. Lumsden & Brewster [24] questioned the social acceptance of gesture-based and speech-based interaction methods in general. Previous studies highlight two critical issues in gesture based interaction in public use. Rico et al. [25] argue that a successful gesture interfaces need to be usable and robust in addition to being socially acceptable. Gestures in general produce physical and cognitive load which has to be overcome by personalized gesture sets [26]. These challenges lead to the exclusion of all indirect gesture ringterfaces from social acceptable everyday digital jewelry. Socially acceptable ringterfaces therefore would support either: 1) conventional computer-like input or 2) secretive gestures.

Subtlety. Costanza et al. [27] studied subtle and intimate interaction using an EMG-based “motionless gesture” system worn on the upper arm under the clothes. This kind of interaction represents the most subtle and unnoticeable interaction the human body can produce using voluntary movement of muscles. Unfortunately, such interaction is difficult to incorporate into ringterfaces. The high information entropy in the finger [4] would produce lots of false positives in detecting any gesture. García-Herranz et al.'s [28] model for classification of communication consists of two axes. *Information* communicated varies from poor to rich on one axis. On the other axis communication *traffic* varies from light to heavy. Subtle communication is therefore rich in information but light in traffic, whereas the opposite is redundant communication which is poor in information but heavy in traffic. This translates to subtle interaction as minimal perceivable interaction.

Natural interaction. Many of the ringterfaces support gesture interaction. Although a popular research topic, gestures may not be the most suitable approach for ringterfaces. Hinckley & Wigdor [22] argue that “it is a common mistake to attribute the naturalness of a product to the underlying input technology” and that “there is no inherently natural set of gestures”. Rico et al. [25] summarized previous research results on naturalness of gestures indicating that natural gesture interaction may not be separated from gestures that support speech and conversations. Mouse-like and keyboard-like ringterfaces are not any more natural than the original indirect input devices which interaction they emulate. Nor are handwriting ringterfaces, except for handwriting tasks. Thinking about the finger-ring particularly as a form factor does raise a question what a natural interaction using a ringterfaces should actually be like. Mundane interactions involving ringterfaces that are already ‘naturalised’ would reduce the perceived level of complexity in use. Normally, rings are mere decorations and have symbolic value. Conventional rings do not have functionality. However, being part of the finger they allow a few interactions that we here take as natural: 1) Pointing with the finger the ring is worn is natural direct input, 2) playing with the ring by rolling it around, moving it along the finger or slightly fix its position which would not seem strange to most people, or 3) taking the ringterface off and putting it on which are natural and unobtrusive interactions (although potentially annoying when repeated).

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3.2 Results

Fig. 1. illustrates the result of the categorization. In the following, we draw a few notions on how specific ringterfaces fit into the above-mentioned criteria.

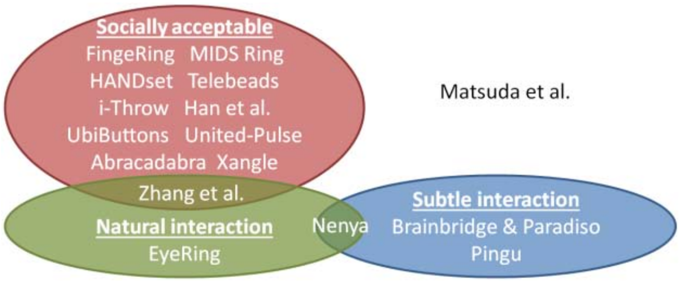

Fig. 1. Ringterfaces categorized by analyzed three characteristics.

Social acceptability. Most of the ringterfaces allow the effect of interaction to be perceived and understood by others. Even HANDset would not differ much from a normal mobile phone headset. Mouse-like pointing would not look strange as long as the cursor can be seen. United-Pulse that does not allow input would also be socially acceptable as its output cannot be perceived by the observers. Use of Nenya, on the other hand, looks mostly like a magical gesture. All indirect gesture ringterfaces that do not relate to existing user interface devices, i.e. Bainbridge & Paradiso's, Pingu and Nenya, were judged to be socially non-acceptable based on the previous findings [24-26] discussed above. Assistive technology ringterfaces, Matsuda et al.'s Braille reading method and EyeRing, are more challenging to categorize. They are only used in situations where there are physically impaired users reading texts they do not perceive in the same way as healthy users. In that sense, if used by healthy users, these ringterfaces would be seen as strange devices.

Subtlety. Pingu and Telebeads employed somewhat similar interaction techniques and United-Pulse only uses a different modality. These ringterfaces can achieve rich information through the codification and light traffic in communication. In this sense subtle interaction can be achieved by embedding the user interaction into some ordinary and unnoticeable voluntary action that does not produce heavy communication traffic due to the use of the ringterface. MIDS Ring or Han et al.'s magnetometer-based method could therefore be used only when masqueraded as normal-looking handwriting. Nenya, on the other hand, does achieve rather light traffic, but it communicates only poor information.

Natural interaction. Only three of the ringterfaces achieve natural interaction by providing interactivity as putting the ring on or taking it off, playing with the ring or pointing with the finger. Zhang et al.'s touchscreen-like ringterface enables the user to point and touch a surface. The only limitation in this technique is that the user usually has to point at a target device of an ambient intelligence enabled environment. The "playful" interaction is only enabled in Nenya. Mundane interactions, taking off and putting on, have not been utilized in any ringterface concept yet.

4 Discussion

The above analysis suggests that the research on ringterfaces has so far been very much technically-focused. It seems that none of the ringterfaces presented to date achieve subtle, socially acceptable and natural interaction. Social acceptability was achieved by 11 ringterfaces, subtle interaction by 3 ringterfaces and natural interaction by 3 ringterface. Only 2 ringterfaces achieve two of the three aspects. Therefore, an alternative paradigm might help us to understand how the vision of digital jewelry in the case of ringterfaces could actually be realized in terms. We suggest that that two major factors affect adoption of ringterfaces in the real world.

First, as the level of automation in our everyday technology raises due to agent technology and context-awareness, we will find less and less need for complex user interaction. Especially in the context of ambient intelligence, this becomes a key question [29]. The automation of routine tasks will release people from executing trivial tasks, and thereby give them additional time to focus on more challenging tasks. In addition, such ambient communication technologies can be considered as a platform to keep social relationships within geographically distributed people [30]. The design of ambient communication technologies will have a considerable impact on the way people communicate and interact in their daily life. The possibilities that arise from such system will not only influence communication processes, but also the way daily activities are organized. Therefore, the requirements to build ambient communication technologies that perform exactly as they are expected to do, and that protects personal data while still allowing easy access to it, are compelling.

Second, we believe end-user programming (EUP) [31] becames an essential part of future ringterfaces. Within an increasing number of domains an important emerging need is the ability for users, who have limited technical knowledge, to compose computational elements into novel configurations. EUP attempts to support naïve users to somehow find ways to control the power of computation to help with their tasks. EUP is becoming a trend in mobile communications e.g. in the form Samsung's *TecTiles*™.

Costanza et al. [27] stated that most of the personal communication through mobile devices is minimal for the most parts. For a future ringterface that enables highly automated and end-user-programmed mobile communications, even a few input commands would suffice. Our on-going work demonstrates how increasing level of automation and EUP come together as a interaction method for making real world mnemonics [32]. The concept supplements smartphones with a finger-ring shaped wearable camera that is used to take photos of the user's environment. EUP enables the user to record macros on the smartphone that are associated with a photo of a familiar scene. Taking another similar photo of the same scene triggers the macro. In this way the user is empowered to use her creativity for making the mnemonics and achieve what she wishes using EUP, yet, automation processes photo comparisons.

5 Conclusion

We analyzed 16 previous ringterface concepts in terms of interaction techniques. Especially gesture interaction seems a popular choice of interaction in the latest concepts. We argued that gesture interaction based ringterfaces will face problems in everyday commercial applications because of low social acceptance of gestures in public places. We suggested two aspects that affect the success of ringterfaces as general-purpose user interfaces. First, the ever-increasing level of automation and future advances in ambient intelligence and context-awareness will affect adoption of gesture interaction based ringterfaces negatively. Simplistic interaction techniques are most likely to prevail. Second, end-user programming is suggested to be the paradigm which is a socially acceptable and flexible step in the near future developments of ringterfaces for everyday use. We outlined our approach and on-going work on development of this kind of ringterfaces. Future research will focus on validating our suggestions and examining how they relate to other form factors of digital jewelry.

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